

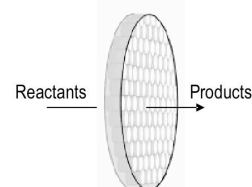
# Nanoporous Material Synthesis with Atomic Level Control!

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**Abstract:** Nanoporous catalytic materials, predominantly in the form of zeolites, have gained wide acceptance as industrial catalysts for oil refining, petrochemistry, and organic synthesis, particularly for molecules with kinetic diameters below 1 nm. **Here we report a facile, flexible route to the synthesis of ultra-uniform heterogeneous catalytic membranes** using a combination of anodic aluminum oxidation (AAO) and atomic layer deposition (ALD) that allows atomic level control of both the pore wall diameters and pore wall composition.

The nanoporous catalytic materials offer unique catalyst environments which:

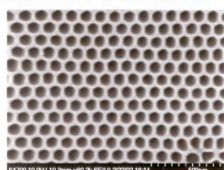
1. provide larger pores than conventional mesoporous materials (for containing large clusters or arrays of catalyst sites, for efficient in-diffusion of large/elaborate molecular precursors or feedstock molecules, and for out-diffusion of large/elaborate product molecules),
2. permit tailoring of channel size and wall composition by ALD (including channel surfaces with hydrophobic, hydrophilic, chiral, or particle anchors and the sequencing of these features along the channels),
3. constrain catalyst mobility, thus hindering agglomeration,
4. control flow of reagents in and out of the catalyst.



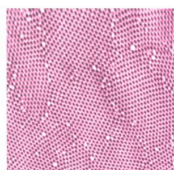
**The nanoporous catalytic membrane concept.**  
AAO membranes are ~ 100 μm thick. They contain ordered arrays of 50 nm through holes.

## Synthetic Route:

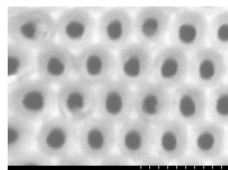
1.



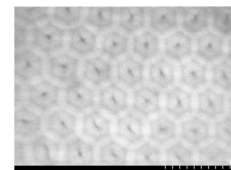
The Field Emission Secondary Electron Microscope (FESEM, left, 40 nm pores) and Atomic force microscope (AFM, right, 5\_5 μm²) images of ANL AAO membranes.



2.



SEM image at left of original 40 nm AAO material. At right is SEM image of AAO membrane coated with 15 nm of alumina. Note the 10 nm pores which are at the limit of the SEM resolution.



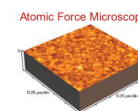
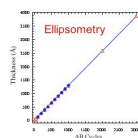
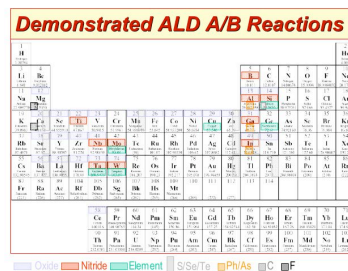
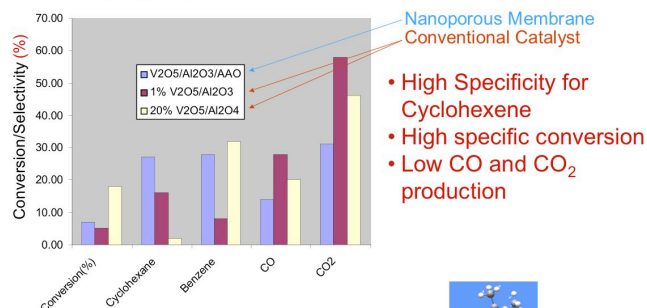
## 1. Anodic Aluminum Oxide (AAO) Membranes

- produced electrochemically
- up to 100 μm thick
- hexagonally ordered arrays of straight channel through holes.
- uniform hole diameters can be synthesized in the range 20 nm to 200 nm.

## 2. ALD Coating

- layer by layer
- any pure or mixed-metal oxide (including alumina), carbide, nitride or metallic film
- along a controllable percentage of the pore length (including 100%)
- Pore diameters can be narrowed from their starting diameter of 20 to 200 nm to dimensions as small as ~1 nm.

## 1st Catalytic Results:

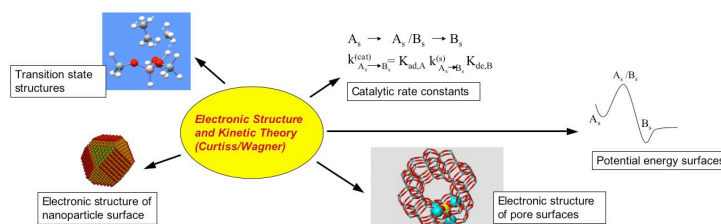


## ALD:

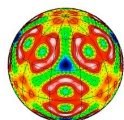
- ALD Enables Precise Thickness Control.
- ALD eliminates "line-of-sight" coating restrictions.
- Aspect ratios of 10000 to 1 now possible.
- RMS Roughness = 4 Å Following 3000 AB Cycles.
- ALD Films are Extremely Flat and Pinhole-Free.

## Future Directions:

### Theory:



Nanoporous Catalytic Membranes: Synthetic Atomic Level Control of Pore Size and Pore Wall Composition, submitted to Nature



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MSD - ANL

